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Science Advisory Report 2013/037

REVIEW OF HARVEST CONTROL RULES FOR PACIFIC SARDINE AND SEASONAL BIOMASS AND MIGRATION IN BRITISH COLUMBIA FOR 2013

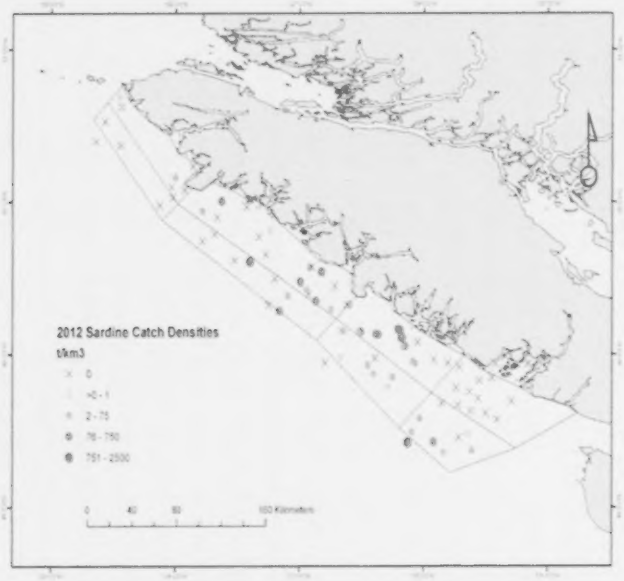

Figure 1. Sardine catch densities (tonnes/km3) for the 2012 WCVI trawl survey). The core survey region is delineated by the outer bounds of the 8 sub regions zones shown above.

Context :

Pacific sardine (Sardinops sagax) from the Northeast Pacific (California Current) population has a distribution that can range between Baja California to southeast Alaska. In winter and spring months, most of the sardine population resides in waters off the California coast. Prior to and during summer months, large aggregations of sardine migrate from key spawning habitat to more northern waters, but migratory patterns can be affected by population size and oceanographic conditions. Typically, most sardines that migrate into British Columbia (B.C.) waters are the larger and older component of the population.

Fisheries & Oceans Canada has been applying a Fishery Management Framework using a harvest control rule that sets the maximum annual total allowable catch (TAC) of sardine based on annually updated biomass estimates of age 1 year and older (1+) fish in the population, an estimated average seasonal migration rate of sardine into Canadian waters, and a regional harvest rate.

Since 1997, an index of the biomass of the migratory component of the sardine population has been determined from an annual summer surface trawl survey off the west coast of Vancouver Island. The index is based on average sardine densities observed for the region, measured in t/km^3. Biomass estimates for unsurveyed areas have been calculated by extrapolating annual trawl survey densities to areas of current and recent fishing grounds.

Both DFO and the sardine fishing industry are interested in exploring alternative approaches to the provision of harvest advice that do not rely on the annual trawl survey. To address these multiple interests,

both the provision of harvest advice and alternative approaches for the provision of harvest advice were examined.

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Pacific Regional Advisory Process. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule.

SUMMARY

- Sardine abundance trends from the population assessment and the west coast of Vancouver Island trawl survey both show decreases in sardine biomass from 2011 to 2012, and the last year for which the population assessment estimates a moderately strong recruitment year class is 2009.
- The estimated 2012 age 1+ California Current sardine population biomass (and 90% confidence interval) was 659,539 (442,717 -876,361) tonnes, as of July 2012 (from the U.S. led stock assessment).
- The estimated 2012 sardine biomass (and 90% confidence interval) for the west coast of Vancouver Island core survey region is 40,377 (14,564 – 71,815) tonnes. The extrapolated 2012 biomass estimate for west coast of Vancouver Island and the mainland inlets is 8,354 tonnes.
- Estimates of the three-year average sardine migration rate into B.C. waters for 2010-2012 are 10.2% and 12.3%, which correspond to forecasts of 67,273 and 81,123 tonnes for average sardine biomass for the season starting in 2013.
- Low 2012 trawl survey sardine density results may not be representative of sardine migration into B.C. waters due to the timing of the survey and delayed favourable oceanographic conditions for sardine.
- Four alternative approaches (scenarios) for the provision of harvest advice were examined. Three of the scenarios were found to have a scientific basis, however there was insufficient information to recommend a single scenario from among the three. One scenario was rejected because it is not sensitive to variations in population biomass and is not precautionary. Harvest options and considerations for each scenario are provided ranging from 7,321 tonnes to 32,977 tonnes.
- Fishery Managers are advised to consider uncertainty associated with biomass forecasting for the fishing season starting in 2013. They are also advised to consider uncertainty associated with localized ecosystem attributes, such as incidental harvest of other species and removal of sardine from important forage habitat of sardine predators.

INTRODUCTION

Species Biology

Sardines are schooling pelagic fish found in relatively warm waters of every ocean with a global distribution restricted to 60°N and 50°S latitude. The population of Pacific sardines (*Sardinops sagax)* in the Northeast Pacific are linked to the California Current ecosystem and the population has undergone long-term fluctuations in abundance for at least 2000 years. In the last century, large abundances occurred throughout the population's range from the early 1900s to the late 1940s. Following that period, their abundance declined and their distribution contracted to small pockets off southern California and Ensenada Mexico. The population has gradually rebuilt

since the 1980s and, as the population size increased, so has the northern extent of its distribution. A resurgence of sardine distribution into B.C. waters has been observed since 1992.

Sardines aged 2 to 4 generally range from 17 to 22 cm (fork length), whereas sardines aged 4 to 8 (and older) generally range from 20 to 25 cm. Year class and recruitment success can vary greatly between years, and a strong year class can comprise a significant proportion of the population for several years. The main spawning grounds for the California Current sardine population are off southern California and northwest Baja, Mexico, but during warm periods, such as during strong El Niño events, environmental conditions may be conducive to sardine spawning in more northern waters, such as off the Oregon, Washington and British Columbia (B.C.) coasts; however, this does not appear to be an annual event.

Ecosystem Considerations

Sardines are a prey species for a variety of marine fishes, mammals, and seabirds. Their seasonal distribution in B.C. waters corresponds with salmon and humpback whale foraging and migrating seasons. Research continues to develop a better understanding of ecosystem processes, including environmental effects on sardine recruitment, and the role that sardines play in ecosystem structure and function.

Species of fish captured along with sardines, in commercial seine and research trawl catches include salmon, spiny dogfish, mackerel, herring and squid. Incidental capture of salmon in the commercial sardine seine fishery is monitored. Area and time closures are implemented to protect sensitive salmon stocks (DFO 2012).

DFO Management Framework and Objectives

The objective of the current management framework is to ensure sustainable resource utilization and generate economic prosperity, accomplished through close collaboration with resource users and stakeholders based on shared stewardship consistent with treaty and Aboriginal rights (DFO 2012).

No formal fishery management agreement exists between Canadian, U.S. and Mexican governing agencies on coordinated approaches to assessment or management frameworks.

In anticipation of reductions in assessment funding, and to allow exploration of other important science questions related to sardine ecology, both DFO and the sardine fishing industry are interested in exploring alternative approaches to the provision of harvest advice that do not rely on a trawl survey to annually estimate migration rates. In light of this, Fisheries Management put forward the following management objectives when considering the development of new harvest control rules:

1. Minimize risk to the status of the stock, to habitat and other ecosystem components (*DFO's Fishery Decision Framework incorporating the Precautionary Approach*);
2. Implement multi-year science advice (e.g. multi-year management plans, harvest levels etc);
3. Enable annual harvest levels that are opportunistic given the variable nature of sardine abundance in B.C. waters; and,
4. Move towards a more stable estimate of migration or a more stable combined migration and harvest rate term in the harvest control rules (HCR).

ASSESSMENT

Method and Sources of Information

Population and B.C. observations

The annual U.S. assessment of the California Current sardine population incorporates fishery catch data (landings and biological data) and research survey data (from acoustic-trawl, aerial, and ichthyoplankton-trawl surveys) into an age structured Stock Synthesis (SS) model which collectively represents sardine abundance from northern Baja Mexico to B.C. Canada (Hill et al. 2012). The methods and results associated with the population assessment are formally reviewed every two to four years, and the current version of the SS model is denoted as "X6e".

Information to characterize sardine size, age, biomass and migration in B.C. waters is based on data from a summer trawl survey off the west coast of Vancouver Island (WCVI). The WCVI trawl survey has been conducted at night since 2006 and has a core survey region (CSR) with a surface area of 16,740 km^2 (Figure 1). The total volume of the WCVI CSR is estimated at 502.2 km^3, based on the assumption that sardines primarily inhabit the upper 30m of the water column where trawl sampling occurs. To annually estimate sardine biomass for the WCVI CSR, average trawl survey sardine catch densities are multiplied by 502.2 km^3 and bootstrapping is used to estimate confidence intervals (Flostrand et al. 2011). Inlets are not included within the CSR due to sampling constraints, but annual average WCVI trawl survey densities have been extrapolated to unsurveyed, nearshore waters (for an area of 3,463 km^2 and a surface volume of 103.9 $km^{3)}$ to estimate additional biomass.

Harvest control rule scenarios

Four HCRs were considered for multi-year HCR and TAC options. To examine the implications of the various HCRs, a range of parameter values were employed for each HCR and hypothetical annual TACs were calculated.

The four HCR scenarios were:

1. the product of a migration rate estimate, a fixed regional harvest rate of 15% and a SS model age 1+ biomass estimate, where the migration rate parameter was determined in one of three different ways;
2. the product of a fixed population harvest rate and a SS model age 1+ biomass estimate, where a range of population harvest rates was considered;
3. the product of a fixed population harvest rate and a SS model age 1+ biomass estimate in excess of 150,000 t, where a range of population harvest rates was considered; and,
4. a range in constant annual TAC amounts.

For each HCR scenario, hypothetical population exploitation rates (ERs) were calculated as the ratios of hypothetical TAC values and age 1+ SS model Semester 1 (July) population biomass estimates corresponding to appropriate summers in the time series. All age 1+ biomass estimates were results from SS model version X6e (Hill et al 2012).

Scenario 1. Migration rate, B.C. harvest rate and Stock Synthesis 1+ biomass (includes status quo)

The first HCR scenario is the product of migration rate (MR), a fixed regional harvest rate (15%) and a SS model age 1+ biomass estimate representing the previous season. The inclusion of MR relies on data from a standardized WCVI trawl survey.

TAC_y = MR x HR_{BC} x Age 1+ SS model $biomass_{y-1}$

where HR_{BC} = 15%

where y = year and y-1 = previous year

Three sets of MRs were considered, representing different degrees of inter-annual variability and actual estimates for the night trawl survey period (2006-2012):

a) a migration rate corresponding to the preceding summer season (e.g. for setting a 2007 TAC, a migration rate representing the 2006 season was used). This set of migration rates had the highest inter-annual variability. Hypothetical TACs and ERs were calculated for the 2007-2012 fishing seasons.

b) a rolling average migration rate corresponding to the 2 or 3 preceding seasons; Hypothetical TACs and ERs were calculated for the 2008-2012 fishing seasons. Scenario 1b) is equivalent to the status quo HCR that uses a rolling average representing migration over the preceding 3 seasons.

c) a constant migration rate representing the average of the 2006-2012 seasons (therefore no inter-annual variability). Hypothetical TACs and ERs were calculated for the 2007-2012 fishing seasons.

Scenario 2. Fraction of Stock Synthesis 1+ biomass

The second HCR scenario is the product of a fixed population harvest rate and a SS model age 1+ biomass estimate and does not depend on annual updates of biomass or migration rate from a standardized WCVI trawl survey.

TAC_y = HR_{Popn} x Age 1+ SS model $biomass_{y-1}$

where HR_{Popn} = a range from 0.02 to 0.05 (with 0.005 increments)

where y = year and y-1 = previous year

Hypothetical TACs were calculated for the 1994-2012 fishing seasons as the product of the previous year's SS model age 1+ biomass estimate (e.g. from the 1993-2011 SS model time series) and across a range of HR_{Popn}. The range of harvest rates used in these scenarios was 2% to 5% because this range encompasses 1) realized estimates of 2006-2012 harvest rates, and 2) values resulting from the product of estimated annual migration rates (2006-2012, Table 1) and a 15% regional harvest rate.

Scenario 3. Fraction of Stock Synthesis 1+ biomass with cutoff

The third HCR scenario is the product of a fixed population harvest rate and a SS model age 1+ biomass estimate in excess of 150,000 t and it does not depend on annual updates of biomass or migration rate from a standardized WCVI trawl survey. The role of the cutoff is to reduce the effective harvest rate with decreases in population biomass estimates as well as leave a critical biomass level below which fishing ceases.

TAC_y = HR_{Popn} x (Age 1+ SS model $biomass_{y-1}$ – 150,000 t)

where HR_{Popn} = a range from 0.02 to 0.05 (with 0.005 increments)

where y = year and y-1 = previous year

As with Scenario 2, hypothetical TACs were calculated for the 1994-2012 B.C. fishing seasons as the product of the previous year's SS model age 1+ biomass estimate (e.g. from the 1993-2011 SS model time series) and across the range of HR_{Popn}.

Scenario 4. Constant annual TAC

The final scenario examined was the application of a constant TAC, requiring no B.C. migration rate updates or any population biomass estimates from the SS model. The range of constant TAC values examined was 15,000-45,000 t (with 5,000 t increments). This range of values was chosen because the mean and median of B.C. fishery TACs during 2002-2012 was approximately 15,000 t and the mean and median of landings from B.C., Washington and Oregon states combined during 2002-2012 was approximately 45,000t. Also a 45,000t value is approximately equal to mean value for output from a Scenario 1 HCR resulting from a HR_{Popn} of 4.5% across the 1994-2012 SS age 1+ biomass values.

Results

Population and B.C. observations

Results of the 2012 sardine population SS assessment model indicates that the age 1+ biomass increased after 1993 and peaked at approximately 1,300,000 t in 1999, 2006 and 2007 (Hill et al. 2012, Figure 2). The assessment further estimates the population to have declined during 2006-2012 with a 2012 age 1+ population biomass estimate (as of July) of 659,539 tonnes (Table 1). The SS model estimates strong recruitment for the 2003 year class, which is believed to have contributed large proportions of biomass to the population for several years and to the peak in biomass in 2006 and 2007. Due to poor representation in commercial catch and survey observations, there is considerable uncertainty associated with the strength of the 2011 year class, but to date there are no indications that it is above average.

Most sardine biomass in B.C. waters is attributed to fish that are greater than 20 cm fork length and age 2 years and older. Collectively, the range in fork length for most sardines sampled in 2012 from B.C. waters was 19-26 cm, with a mean of approximately 23 cm and a peak mode at ~21-22 cm and a secondary mode at ~ 23-24 cm. Preliminary ageing results from otoliths collected during the 2012 WCVI trawl survey indicate that approximately 30% of the sardines were from the 2010 year class and 15% were from the 2009 year class.

Annual estimates of sardine trawl survey catch densities and biomass show a declining trend from 2006 to 2010, an increase in 2011 and then a decrease in 2012 (Table 1). The 2012 mean WCVI survey sardine catch density estimate is 80.4 t/km^3, which corresponds to a biomass estimate of 40,377 t for the WCVI CSR and 8,354 t for inlet extrapolation. Annual age 1+ population migration rate estimates show the same trends as density and biomass estimates, a decrease from 2006 to 2010, an increase in 2011, and a decrease in 2012 (Table 1).

Table 1. Summary results for 2006-2012 associated with estimates from the California Current Pacific sardine population assessment (version SS X6e, Hill et al. 2012), the west coast of Vancouver Island (WCVI) summer night trawl surveys, biomass extrapolation into unsurveyed Pacific Fishery Management Area (PFMA) groupings and BC fishery total allowable catch (TAC) and landings. Lower (LL) and upper (UL) limits for 90% confidence intervals for core survey region density and biomass estimates included. No WCVI survey was conducted in 2007.

Year	2006	2007	2008	2009	2010	2011	2012
Population age 1+ biomass (tonnes)							
	1,365,980	1,356,860	1,286,760	1,106,180	1,077,220	898,150	659,539
WCVI core survey region sardine catch density observations							
Number of trawl tows	44		60	95	57	68	67
Proportion positive sardine	0.93		0.67	0.49	0.65	0.6	0.45
Mean sardine density (t/km^3)	759.9		420	378.3	163.2	301.0	80.4
LL 90%	496		224	242	70	194	29
UL 90%	1,055		662	531	277	440	143
Sample standard deviation	1148		1062	852	485	664.3	286.5
CV of the mean	0.23		0.33	0.23	0.39	0.27	0.43
WCVI core survey region biomass (tonnes), representing 502.2 km^3							
WCVI core survey region	381,622		210,924	189,982	81,959	151,162	40,377
LL 90%	249,091		112,493	121,532	35,154	97,427	14,564
UL 90%	529,821		332,456	266,668	139,109	220,968	71,815
WCVI inlets biomass (tonnes), PFMA 20, 23-27, representing 31.4 km^3							
	23,861		13,188	11,879	5,124	9,451	2,525
Mainland inlets biomass (tonnes), PFMA 7,8,9,10 and 12, representing 72.5 km^3							
	55,093		30,450	27,427	11,832	21,823	5,829
Sum of WCVI core survey region and inlet biomass (tonnes), representing 606.1 km^3							
	460,575		254,562	229,288	98,916	182,436	48,731
Migration rate (% population age 1+ biomass)							
WCVI	27.9		16.4	17.2	7.6	16.8	6.1
WCVI + IE	33.7		19.8	20.7	9.2	20.3	7.4
B.C. fishery (tonnes)							
TAC	13,500	19,800	12,491	18,196	23,166	21,917	27,279
Landings	1,558	1,507	10,435	15,334	22,223	20,718	19,172
B.C. fishery (% population age 1+ biomass)							
TAC	1.0	1.5	1.0	1.6	2.2	2.4	4.1
Landings	0.1	0.1	0.8	1.4	2.0	2.3	2.9

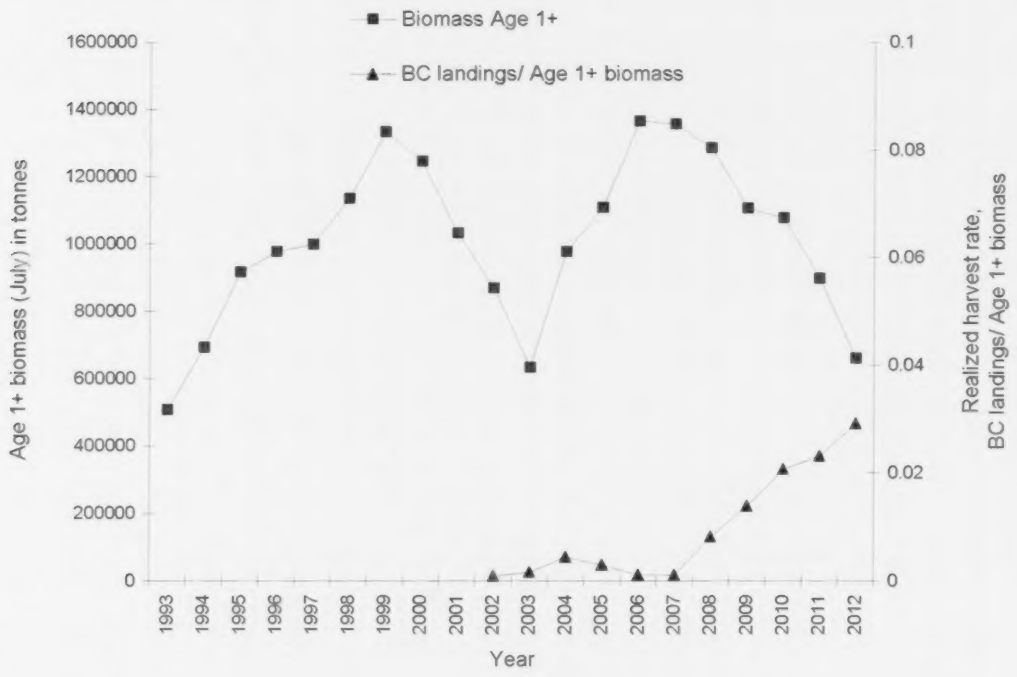

Figure 2. Estimates of 1993-2012 population age 1+ biomass and 2002-2012 B.C. fishery realized age 1+ population harvest rates. Age 1+ biomass estimates from Hill et al 2012.

Harvest control rule scenarios

Scenario 1 HCRs require migration rate estimates from a standardized WCVI trawl survey, which may provide a biased estimate of stock biomass during years of unusual environmental conditions or due to mismatch of survey and migration timing, such as may have been the case for the 2012 observations. The HCR scenario for Scenario 1.b is essentially equivalent to the currently approved HCR and provides Fisheries Management with annual updates and is responsive to annual changes in sardine abundance (Table 2).

Scenario 2 HCRs, which use a constant fraction of the SS model age 1+ biomass are responsive to annual changes in sardine population abundance but do not require annual biomass and migration rate estimates from a standardized WCVI trawl survey. The use of this HCR may reduce DFO workload and enable flexibility in research efforts if survey estimates are not annually required to advise on harvest levels for subsequent fishing seasons. This HCR also accounts for some ecosystem considerations by removing a proportion of the population, rather than a constant amount.

Scenario 3 HCRs have the same sensitivity to population fluctuations as Scenario 2 HCRs and also do not require annual biomasss and migration rate estimates from a standardized trawl survey. At equal HR_{Popn} fractions, Scenario 3 HCRs are more precautionary than Scenario 2 HCRS when sardine biomass is low because the cutoff has a ramping down effect on the effective harvest rates when the population biomass decreases.

Scenario 4 HCRs provide stability for the fishery but do not respond to changes in population fluctuations, including ecosystem considerations. Therefore at low biomass levels, effective

exploitation rates will be relatively high and at high biomass levels, effective exploitation rates will be relatively low.

Harvest options

Applying the current HCR the harvest options are 10,091 and 12,168 tonnes (Table 2, scenario 1.b).

Harvest options resulting from alternative HCR scenarios are also included for consideration. Table 2 shows Scenario 1 HCR results from applying 2012 estimates of migration (scenario 1b) and from applying 2006-2012 mean estimates of migration (scenario 1c). Table 3 shows Scenarios 2 HCR results from applying population harvest rate parameters of 3%, 4% and 5%.

Table 2. Harvest options for the 2013 fishing season based on Scenario 1 harvest control rule scenarios associated with varying the migration rate parameter.

Pacific sardine population age 1+ biomass estimate from Stock Synthesis model X6e (July)			**659,539**
HCR Scenario	1.a	1.b	1.c
Years	2012	2010-2012	2006-2012
Migration rate parameter			
WCVI CSR	6.1%	10.2%	15.3%
WCVI CSR + Inlet extrapolation	7.4%	12.3%	18.5%
2013 BC biomass forecast (t)			
WCVI CSR	40,232	67,273	100,909
WCVI CSR +Inlet extrapolation	48,806	81,123	122,015
B.C. regional harvest rate	15%	15%	15%
Harvest options (t)			
WCVI CSR	6,035	10,091	15,136
WCVI CSR +Inlet extrapolation	7,321	12,168	18,302

Table 3. Harvest options for the 2013 fishing season based on Scenarios 2 and 3 harvest control rule associated with setting the population harvest rate parameter at 3%, 4% and 5%.

Age 1+ sardine population biomass estimate from Stock Synthesis model X6e (July)			659,539
Cutoff (t)			150,000
Harvest rate value (%)	3.0%	4.0%	5.0%
Harvest option with cutoff (t)	15,286	20,382	25,477
Harvest option without cutoff (t)	19,786	26,382	32,977

Sources of Uncertainty

Since the resurgence of a B.C. sardine fishery, a substantial portion of landings have been from PFMAs where biomass estimates have been extrapolated; however, assumptions associated with extrapolating average WCVI survey densities and spatial extents of the inshore areas have not been tested and confidence intervals cannot be assigned to extrapolated estimates.

There is uncertainty about the representativeness of the 2012 survey results because sardine distribution and abundance is confounded by in-season movements, particularly related to ocean conditions.

There has been debate over possible detrimental effects to the sardine population's productivity and age-structure by each country (the U.S., Mexico and Canada) independently setting harvest allowances. Concerns include the possibility that the collective harvest rate of the three countries may exceed harvest rates applied in individual countries. Other concerns include unknown effects on stock structure and reproductive capacity from targeting younger components of the population (e.g. from southern California) versus older and larger components of the population (e.g. from Washington, Oregon and B.C.). The impact of these concerns on providing harvest advice in B.C. waters can best be addressed using Management Strategy Evaluation.

There is also uncertainty associated with possible ecological effects from the incidental capture of other species (e.g. salmon), and removal of sardine from important foraging habitat of sardine predators (e.g. humpback whales).

The recent B.C. sardine data time series is relatively short (~10 years) for use in estimating migration rates and evaluating the relative performance of the HCR by means of commonly used performance measures.

Stock Synthesis population biomass estimates, used in HCRs and for estimating migration, have considerable uncertainty due to model complexity and assumptions. Inter-annual changes to modeling methods can result in substantial changes to both total biomass and biomass for different age and size components of the population, which directly affects HCR outcomes. Key sources of uncertainty in Stock Synthesis outputs include uncertainties in: 1) each of the biomass indices, 2) mortality estimates, 3) representation of length and age relationships, and 4) recruitment estimates.

CONCLUSIONS AND ADVICE

Results of the U.S. led 2012 sardine spawning biomass assessment indicate that the age 1+ biomass increased after 1993 and peaked at approximately 1,300,000 t in 1999, 2006 and 2007, then declined during 2006-2012 with a 2012 age 1+ population biomass estimate (as of July) of 659,539 tonnes There is no evidence of strong recruitment since 2009.

Similarly annual estimates of sardine densities and biomass, based on B.C. trawl surveys, show a declining trend from 2006 to 2010, an increase in 2011 and then a decrease in 2012. The 2012 mean WCVI survey sardine catch density estimate is 80.4 t/km^3, which corresponds to a biomass estimate of 40,377 t for the WCVI CSR and 8,354 t for inlet areas. Annual age 1+ population migration rate estimates show the same trends as density and biomass estimates, a decrease from 2006 to 2010, an increase in 2011, and a decrease in 2012. However, low 2012 trawl survey sardine density results may not be representative of sardine migration into B.C. waters due to the timing of the survey and delayed favourable oceanographic conditions for sardine.

Three of the scenarios were found to have a scientific basis for the provision of scientific advice, however, there was insufficient information to recommend a single scenario from among the other three scenarios. Specific considerations for each scenario and additional management advice are outlined below:

- HRC Scenarios 1-3 were found to have a scientific basis for the provision of scientific advice. Scenario 4 HCR was rejected because it is not sensitive to variations in population biomass and is not precautionary.
- From the available literature there is a theoretical basis to support Scenario 2 and 3 HCRs because they decrease inter-annual variation in realized exploitation rates. Further improvements that could be made to decrease interannual variability in migration rate estimates using available data, but which would require additional research to implement.
- Scenarios 2 and 3 HCR may allow for population harvest rates to vary differently compared to regional harvest rates resulting from Scenario 1 HCRs.
- No recommendation on a preferred HCR scenario was possible (of Scenarios 1-3) because performance measures to evaluate HCRs have not been identified for this fishery and stock and because performance measures would need to be evaluated in the context of a dynamic operating model, which is lacking.
- No specific recommendation has been made for population harvest rates for Scenarios 2 and 3 HCRs. A range in population harvest rates of 2-5% for Scenarios 2 and 3 HCRs encompasses 1) realized estimates of 2006-2012 age 1+ population exploitation rates, and 2) values resulting from the product of estimated annual migration rates (2006-2012) and a 15% regional harvest rate. However, realized values from past years will not reflect current conditions if migration rates are changing significantly over time.
- In order to provide further advice on the scenarios considered, it would be necessary to identify performance measures to evaluate HCR scenarios in a population-level management strategy evaluation (preferably in conjunction with the U.S. and Mexico) or a simpler BC-level simulation study (e.g., including covariates, such as ocean conditions).
- If Scenarios 2 or 3 harvest control rules are considered, an analysis should be undertaken to determine the risk of reducing the frequency of the annual trawl survey and associated implications on the robustness of the advice.
- Efforts should be made to continue the collection of B.C. sardine biological data (survey and fishery samples) and ecological and oceanographic data.

- Fishery Managers are advised to consider uncertainty associated with biomass forecasting for the fishing season starting in 2013. They are also advised to consider uncertainty associated with localized ecosystem attributes, such as incidental harvest of other species and removal of sardine from important forage habitat of sardine predators.
- An assessment of the impact of using population age 1+ biomass in the B.C. fishery HCR, when most fish in B.C., Washington and Oregon waters are primarily age 2 and older, is recommended. Additionally, it is recommended that, in conjunction with the U.S., an assessment of the impact of fishing components of the population off California and Ensenada Mexico that are less than age two is conducted.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 29th and 30th, 2013 Regional Peer Review meeting on the Review of the harvest control rule and harvest advice for Pacific sardine in British Columbia waters for 2013 and 2014. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO 2012. Pacific Region Integrated Fisheries Management Plan for Pacific Sardine (June 1, 2012 to February 9, 2015).

Flostrand, L., Schweigert, J., Detering, J., Boldt, J., and MacConnachie, S. 2011. Evaluation of Pacific sardine stock assessment and harvest guidelines in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/096.

Hill, K.T., Crone, P., Lo, N.C.H., Demer, D.A., Zwolinski, J.P., and Macewicz, B.J. 2012. Assessment of the Pacific sardine resource in 2012 for U.S. management in 2013. Pacific Fishery Management Council, Nov 2012 Briefing Book, Agenda Item I.2.b. 193 p.

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Centre for Science Advice (CSA)
Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Road,
Nanaimo, BC V9T 6N7

Telephone: (250) 756-7208
E-Mail: CSAP@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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